10/577203 EX 3
IAP20 Rec'd PCT/PTO 27 APR 2006

06796-PT12/Hi
15.10.2004

ELECTRIC DRIVE UNIT FOR GENERATING AN OSCILLATING MOVEMENT

The invention pertains to an electric drive unit for generating an oscillating movement. The invention furthermore pertains to a small electric appliance with such a drive unit, as well as a method for manufacturing a corresponding drive unit.

Drive units for generating an oscillating movement are used, for example, in electric toothbrushes or electric razors. For example, DE 28 20 437 A1 discloses an electric toothbrush with an oscillating armature motor. The oscillating armature motor is used for realizing an oscillating rotational movement of a shaft that carries a brush element. The rotational movements are influenced by torsion springs and damping elements such that a desired motion sequence is adjusted.

An oscillating appliance, particularly an electric toothbrush, is also known from US 5,613,259. This appliance features a mechanical oscillator that is driven by an electric motor. The electric motor is controlled in dependence on the oscillating frequency of the mechanical oscillator that is determined by means of a sensor such that the mechanical oscillator also remains resonant under a varying load. The mechanical oscillator is realized in the form of a spring-mass system that may comprise a coil spring or a torsion rod.

In order to achieve a largely optimal operation of the electric drive unit for generating an oscillating movement, the drive unit should be excited with a frequency that largely corresponds or lies close to its resonant frequency. However, the resonant frequency not only changes with the load of the drive unit, but is

also detuned due to manufacturing tolerances associated with series production. Although this detuning can be compensated by regulating the excitation frequency, such a control results in increased manufacturing costs. In addition, a change of the excitation frequency is undesirable in certain applications.

Consequently, the invention is based on the objective of realizing a largely optimal electric drive unit for generating an oscillating movement with the least expenditure possible.

This objective is attained with the combination of characteristics disclosed in Claim 1.

The inventive electric drive unit for generating an oscillating movement features a stator, a rotor and a torsion element. The peculiarity of the drive unit according to the invention can be seen in that a tuning element is provided that acts upon the torsion element and serves for mechanically tuning the resonant frequency of the drive unit.

The invention provides the advantage that the drive unit allows an optimal conversion of the electric driving energy into the oscillating movement regardless of possible manufacturing tolerances such that a comparatively low electrical power suffices for the operation of the inventive drive unit.

The drive unit according to the invention is preferably realized such that the tuning element fixes the torsion element at a variable location of the torsion element. In this case, the tuning element may be arranged on the stator such that it can be displaced and fixed in position. The tuning element, in particular, may be displaceable parallel to the longitudinal axis of the

drive unit. For this purpose, the tuning element may engage, for example, into at least one groove in the stator. A design of this type can be realized with a relatively low expenditure and makes it possible to easily tune the resonant frequency of the inventive drive unit.

With respect to its simple handling, it is particularly advantageous that the tuning element is realized in the form of a clamping device. In this case, the tuning element may comprise, for example, two parts and at least one connecting element for pulling together the two parts.

The torsion element is usually fixed on the rotor. In one preferred embodiment of the drive unit according to the invention, the rotor features a hollow shaft. In this case, it is particularly advantageous that the torsion element is at least partially arranged within the hollow shaft. This makes it possible to realize the inventive drive unit in a very compact fashion. The torsion element is preferably realized in the form of a torsion rod that can be manufactured with very strict tolerances and hardly requires any structural space, particularly in combination with the hollow shaft.

The inventive drive unit may feature a housing with a recess in the region of the tuning element. This makes it possible to carry out the tuning of the resonant frequency when the drive unit according to the invention is already completely assembled.

In one preferred embodiment of the inventive drive unit, the stator features permanent magnets and at least one coil. The rotor preferably features an armature of a magnetizable material.

The invention furthermore pertains to a small electric appliance equipped with the inventive drive unit. The small appliance according to the invention is preferably realized in the form of an electric toothbrush or an electric razor. Appliances of this type are frequently operated independently of the electric power supply by means of a battery such that the comparatively low power consumption of the inventive drive unit has positive effects on the time of operation that can be achieved with one battery charge.

The inventive method pertains to the manufacture of an electric drive unit for generating an oscillating movement, wherein the drive unit features a stator, a rotor and a torsion element. The peculiarity of the method according to the invention can be seen in that the resonant frequency of the drive unit is mechanically tuned by the torsion element after the assembly of the drive unit.

The scope of the method according to the invention includes embodiments, in which a region of the torsion element that participates in the oscillating movement can be varied in order to adjust the drive unit to a desired resonant frequency. For this purpose, the torsion element can be fixed on a tuning element, wherein the location at which the tuning element engages on the torsion element is chosen such that the drive unit has the desired resonant frequency. In order to achieve a reliable tuning of the resonant frequency, the drive unit is excited such that it carries out an oscillating movement, and the location of the torsion element at which the tuning element needs to be fixed is determined from the oscillating movement of the drive unit. In one preferred embodiment of the inventive method, an excitation by pulses is used for

causing the oscillation of the drive unit. The location of the torsion element at which the tuning element needs to be fixed can be determined, for example, from the decay behavior of the oscillating movement. The torsion element is preferably fixed in the rotational position that the rotor assumes when the drive unit is switched off.

The invention is described in greater detail below with reference to the embodiments that are illustrated in the figures and in which the inventive drive unit is respectively intended for use in an electric toothbrush.
The figures show:

Figure 1, a top view of a first embodiment of a drive unit realized in accordance with the invention;

Figure 2, a longitudinal section through the first embodiment of the inventive drive unit along the line A-A in Figure 1;

Figure 3, another longitudinal section through the first embodiment of the inventive drive unit, wherein the plane of section is turned relative to Figures 2 by 90° about the longitudinal axis of the inventive drive unit;

Figure 4, a cross section through the first embodiment of the inventive drive unit along the line B-B in Figure 1;

Figure 5, a cross section through the first embodiment of the inventive drive unit along the line C-C in Figure 1, and

Figure 6, a cross section through a second embodiment of the inventive drive unit along the line C-C in Figure 1.

Figure 1 shows a top view of an embodiment of a drive unit 1 that is realized in accordance with the invention. The drive unit 1 features an elongated housing 2, from one face of which a hollow shaft 3 protrudes that extends parallel to the longitudinal axis of the drive unit 1. A connection piece 4 for receiving a not-shown toothbrush attachment is coaxially inserted into the axial end of the hollow shaft 3 that is situated outside the housing 2 and then connected to the hollow shaft 3 in a rotationally rigid fashion. The housing 2 features a window-shaped recess 5 on one of its longitudinal sides, namely in the opposite end region referred to face on which the hollow shaft 3 protrudes from the housing 2. An adjusting element 6 arranged in the interior of the housing 2 is visible through the recess 5, wherein this adjusting element can be displaced parallel to the longitudinal axis of the drive unit 1 and is described in greater detail further below. Details regarding the internal design of the drive unit 1 are illustrated in the sectional representations according to Figures 2-5 and in the sectional representation of a second embodiment according to Figure 6.

Figure 2 shows a longitudinal section through the first embodiment of the drive unit 1 along the line A-A in Figure 1. Figure 3 shows another longitudinal section, in which the plane of section is turned relative to Figure 2 by 90° about the longitudinal axis of the drive unit 1. According to Figures 2 and 3, the hollow shaft 3 continues into the housing 2 and is rotatably supported relative to the housing 2 in two bearings 7. The bearings 7 are arranged in a coil form 8. An

armature 9 is arranged on the hollow shaft 3 in a rotationally rigid fashion between the two bearings 7. A torsion rod 10 extends within the hollow shaft 3 coaxial to the hollow shaft 3 and protrudes from the hollow shaft 3 with both of its axial ends. In the region of its first axial end, the torsion rod 10 is connected to the connection piece 4 and therefore also to the hollow shaft 3 in a rotationally rigid fashion. In the vicinity of its second axial end, the torsion rod 10 is clamped into the adjusting element 6 in a rotationally rigid fashion and thusly connected to the housing 2 in a rotationally rigid fashion. This means that a torsionally elastic suspension of the hollow shaft 3 including the connection piece 4 and the armature 9 is realized on the housing 2 by means of the torsion rod 10. Permanent magnets 12 are arranged radially adjacent to the armature 9 on carrier plates 11. The carrier plates 11 are arranged on the inside of the housing 2 diametrically opposite of one another. A stationary stator 13 and a rotor 14 that is rotatable relative to the stator 13 are realized with the components illustrated in Figures 3 and 4. The housing 2, the coil form 8, the carrier plate 11 and the permanent magnets 12 can be assigned to the stator 13. The hollow shaft 3 with the connection piece 4 and the armature 9 form the components of the rotor 14. The stator 13 and the rotor 14 are coupled to one another in a torsionally elastic fashion with the aid of the torsion rod 10.

Figure 4 shows a cross section through the first embodiment of the drive unit 1 along the line B-B in Figure 1. According to Figure 4, the armature 9 has an elongated cross-sectional shape and is arranged in an oblong hollow space 15 in such a way that it can be slightly turned in both rotating directions relative to the idle position shown. The coil form 8 carries at

least one coil 16 that is only partially illustrated in Figure 4. When a current flows through the coil 16, a magnetic field is generated in the armature 9 such that a magnetic interaction with the permanent magnets 12 occurs in the region of the radial surfaces of the armature 9 that are situated adjacent to the permanent magnets 12, wherein this magnetic interaction causes the armature 9 to be displaced from its idle position and therefore the hollow shaft 3 to be slightly turned. An alternating current feed to the coil 16 makes it possible to achieve an alternating movement of the armature 9 in both rotating directions referred to its idle position such the an oscillating rotational movement of the rotor 14 occurs. This oscillating rotational movement is promoted by the torsion rod 10 that respectively turns the rotor 14 back into the idle position of the armature 9 and forms an oscillatory spring-mass system together with the rotor 14. The amplitude of the oscillating rotational movement becomes particularly high if the excitation by means of the current-carrying coil 16 takes place with the resonant frequency of the spring-mass system. The excitation energy can be transmitted most effectively within the range of the resonant frequency such that the excitation energy required for a desired amplitude assumes a minimum value. In order to operate the drive unit 1 as efficiently as possible, the resonant frequency of the spring-mass system should correspond as precisely as possible to the excitation frequency or to a predetermined value in the vicinity of the excitation frequency. In the series production of several drive units 1, however, the resonant frequencies are detuned due to manufacturing-related tolerances of the components forming the drive unit 1. In order to solve this problem, the invention proposes that the resonant frequency of the spring-mass system is mechanically tuned after its assembly. The tuning is

respectively achieved in that the effective length of the torsion rod is varied with the aid of the adjusting element 6. This procedure is discussed in detail below with reference to Figure 5.

Figure 5 shows a cross section through the first embodiment of the drive unit 1 along the line C-C in Figure 1. Consequently, the plane of section extends through the adjusting element 6 that consists of an upper part 17 and a lower part 18. The parting plane between the upper part 17 and the lower part 18 of the adjusting element 6 extends parallel to the longitudinal axis of the drive unit 1. The upper part 17 of the adjusting element 6 engages into one respective groove 19 in the coil form 8 that extends parallel to the longitudinal axis of the drive unit 1 on both sides and can be moved in this direction only. The upper part 17 is screwed to the lower part 18 with two screws 20 that are inserted into through-bores 21 in the upper part 17 of the adjusting element 6 and engage into threaded bores in the lower part 18 of the adjusting element 6. When the screws are tightened, the torsion rod 10 is clamped between two splines 23 that are realized parallel to the longitudinal axis of the drive unit 1 in the upper part 17 and in the lower part 18 of the adjusting element 6 and the wall surfaces of which are pressed against the cylindrical outer surface of the torsion rod 10. This causes the torsion rod 10 to be non-positively fixed on the adjusting element 6. The adjusting element 6 is simultaneously blocked from moving parallel to the longitudinal axis of the drive unit 1 because the torsion rod 10 is rigid in this direction. The screws 20 are accessible through the recess 5 in the housing 2 in order to be tightened and loosened. The tuning of the resonant frequency of the spring-mass system of the drive unit 1 can be carried out as described below:

The torsion rod 10 is clamped into the adjusting element 6 in the rotational position that it assumes as its idle position due to the effect of the permanent magnets 12 on the armature 9. Before the torsion rod 10 is fixed in position by tightening the screws 20, a preliminary tuning process is carried out by displacing the adjusting element 6 into the position in which the desired resonant frequency of the spring-mass system is presumably reached. In this case, the effective length of the torsion rod 10 is adjusted with the aid of the adjusting element 6 such that the resonant frequency of the spring-mass system is influenced accordingly. The effective length of the torsion rod 10 corresponds to the distance between the location at which the torsion rod 10 is fixed on the connection piece 4 and the location at which the torsion rod 10 is fixed on the adjusting element 6. The resonant frequency rises when the effective length of the torsion rod 10 is shortened, i.e., if the adjusting element 6 is displaced toward the hollow shaft 3. Vice versa, the resonant frequency is lowered if the effective length of the torsion rod 10 is extended by increasing the distance between the adjusting element 6 and the hollow shaft 3. After this preliminary adjustment, the drive unit is excited by pulses such that it carries out an oscillating movement, and the effective resonant frequency of the spring-mass system for the current position of the adjusting element 6 is determined from the decay behavior of the oscillating movement. The deviation between the effective resonant frequency and the desired resonant frequency is then used for determining the distance, by which the adjusting element 6 needs to be displaced in order to reach the desired resonant frequency, for example, with the aid of an empirically prepared table. The adjusting element 6 is then displaced by the determined distance. The position of the adjusting element 6 can be checked with

another excitation by pulses. If so required, the adjusting element 6 is readjusted until the effective resonant frequency of the spring-mass system corresponds to the desired resonant frequency with a predetermined accuracy. The adjusting element 6 is then permanently fixed in position.

According to Figures 4 and 5, the torsion rod 10 according to the first embodiment of the inventive drive unit 1 has a circular cross section. The scope of the invention also includes alternative designs of the torsion rod 10. One possible variation is illustrated in Figure 6.

Figure 6 shows a cross section through a second embodiment of the drive unit 1 along the line C-C in Figure 1. The torsion rod 10 has a square cross section in the second embodiment. The departure from the rotationally symmetrical design of the torsion rod 10 in the second embodiment makes it possible to positively secure the torsion rod 10 with the adjusting element 6 from turning. The splines 23 used in the first embodiment for fixing the torsion rod in the upper part 17 and the lower part 18 of the adjusting element 6 may also be used in this case. The second embodiment of the drive unit 1 also corresponds to the first embodiment with respect to its remaining design and its function.